USING SENTINEL SATELLITE IMAGE TO ESTIMATE BIOMASS OF MANGROVE FOREST IN VINH QUANG COMMUNE, TIEN LANG DISTRICT, HAI PHONG CITY

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SUMMARY
This research tested the use of geographic information systems using Sentinel 1 and Sentinel 2 satellite data to estimate biomass mangrove forest in Vinh Quang commune, Tien Lang district, Hai Phong province. 15 sample plots (10 m × 10 m) in the field were established for making models and evaluation, the satellite images for processing in 2017 were provided freely by ESA Corporation. The study created land cover and biomass maps from field allometric equations and estimated results from the model by maximum likelihood classification and the regression model, respectively. For land cover accuracy assessment, Kappa index was employed with 93% accuracy. NDVI, SAVI were representative indices of optical Sentinel 2 images, similarly, VV and VH backscatter, VV/VH and VH/VV from Sentinel 1A images. The study showed that Sentinel 1 backscatters were unable to generate model due to quite low R^2. Compare to optical images, the NDVI index was used for biomass estimating, the total biomass was about 67,983.12 tons, average: 153.94 ± 27.01 ton/ha, maximum: 223.14 ton/ha. By comparing real numbers and estimated numbers, the results were acceptable, 23.8% average. We conclude that the optical Sentinel 2 has been more suitable to make estimating the model for mangrove biomass at a small-scale level, especially for commune level.
Keywords: Biomass, mangroves, Sentinel 1, Sentinel 2, vegetation indices.

1. INTRODUCTION

Mangroves ecosystems play an important role in ecosystems and people. According to the Food and Agriculture Organization (FAO), the area of mangroves in Vietnam is 270,000 hectares in 2015 and it is increasing due to government and donor-funded planting efforts and mangrove policy. In particular, mangroves are considered as a precaution against natural impacts such as salinization, sea level rising, wave breaking, and landslide. These effects are further enhanced by climate change (Alongi, 2008). Along with the ability of mangrove trees to absorb and store carbon, mangrove ecosystems are being conserved and developed to create carbon pools and reduce greenhouse gases emissions. In addition, mangroves provide cultural, ecotourism and cultural values. Therefore, the monitoring and management of mangroves are more concerned (Hong and San, 1993). To monitor the forest, besides mapping the status of forest distribution, the calculation of forest biomass is very important. Forest biomass indicates both the area and the forest inventory. Accurate biomass production will be an important parameter in addressing climate change adaptation options.

There have been many types of research related to mangrove biomass estimation, from traditional methods such as cutting down, using statistical estimation (Alongi, 2002). These calculations give accurate but labor-intensive measurements and costs, not applicable to large-scale or quite costly (Clark, Brown et al., 2001). In addition, the tidal regime and deviation of the sampling location also affect the results of the study. Consequently, the method of estimation of efficiency should reduce costs, time and increase accuracy, even on a large scale. The application of GIS effectively solved this problem with a great deal of research over the past three decades, including a variety of photographic materials such as optical images, radar images…

Numerous types of remote sensing data that have been used in mapping and monitoring mangroves, including optical data and RAR Real Aperture Radar (Giri, Ochieng et al., 2011). Each type of remote sensing data has its own advantages and disadvantages, such as the optical image is usually affected by clouds and weather but is often provided in multi-spectral, extremely effective bands such as NIR, RED, the vegetation indices (Bannari, Morin et al., 1995). Radar images are unaffected by clouds and weather but affected by the tidal regime (Proisy, Mougin et al., 2000). Biomass estimation gives the most accurate results when applied to a single species in the mangrove forest (Pham, Yoshino et al., 2017). Radar band L has been used widely in estimating forest biomass in general and mangroves in particular due to the long wavelength (20 cm) (Le Toan, Thuy, et al., 1992). There have been studies showing that radar band C (6 cm wavelength) was difficult to estimate biomass based on leaf index, but accuracy was very low (Jose Alan A.Castillo et al., 2017). The research on biomass for mangroves is still limited and often focus on changing in areas and carbon stocks, focusing on northern coastal areas such as Hai Phong, Quang Ninh, Thai Binh; Southern Vietnam: Ca Mau, Kien Giang and Can Gio… (Pham and Yoshino, 2012).

In Hai Phong, the coastal area of Tien Lang lies to the south of the North-East Coast of Vietnam. This is the most accretion area of Hai Phong and has the potential to expand the largest reserve land reserve. Tien Lang mangrove forest is considered a very useful coastal resource for economic, social and ecological development. Along with the development of GIS and remote sensing, from 2014 until now, Sentinel 1 satellite provides C-band radar images (Balzter, Cole et al. 2015) and the Sentinel 2 satellite provides high-resolution optical imagery (Drusch, Del Bello et al. 2012). They are extremely important materials form the European Space Agency (ESA) in evaluating the status of mangroves. Therefore, this study was carried out to evaluate the use of sentinel images 1 and 2 in estimating mangrove biomass.

2. MATERIAL AND METHODS

2.1. Study Site

The study site belongs to Vinh Quang commune. That covers a part of the coastal area of Tien Lang district, Hai Phong, about 120km from the Hanoi capital. It borders Quang Ninh province to the north, Hai Duong province to the west, Thai Binh province to the south, and the Gulf of Tonkin to the East. Vinh Quang commune covers an area of 10.04 km^2 (1,004 ha), including both mangrove forest and agriculture land (Hai Phong Port news).

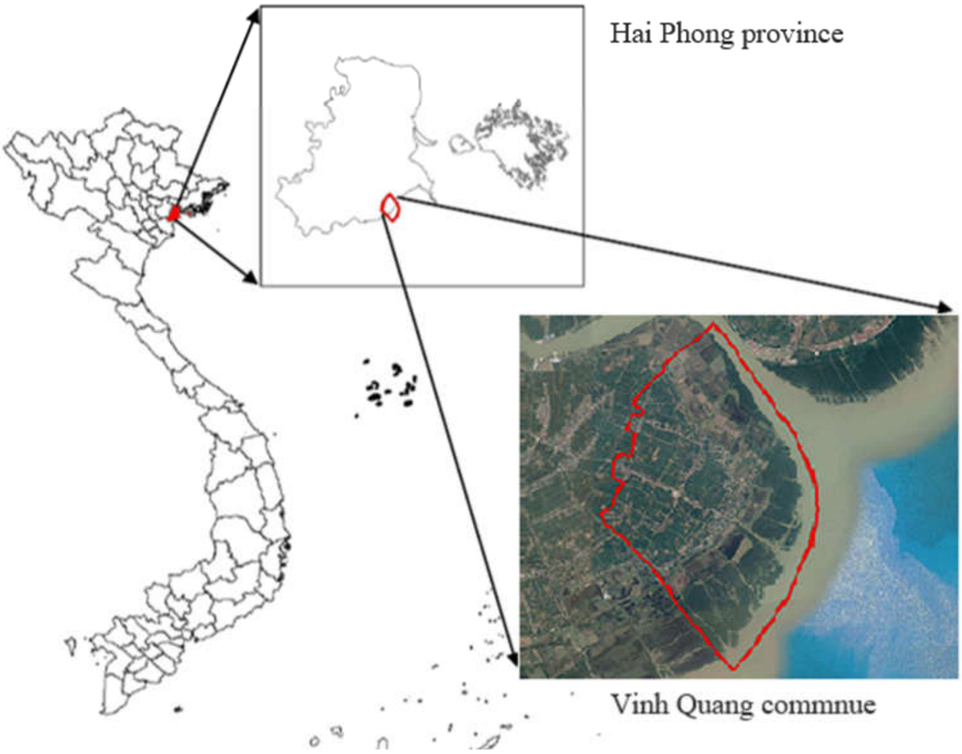

Figure 1. Location of the study site

2.2. Materials

The polar-orbiting Sentinel 2 satellites placed in the same orbit, phased at 180° to each other, the temporal resolution is 5 days with 2 satellites, supporting monitoring vegetation. Optical Sentinel 2 image: level 1C product: top of atmosphere reflectances in fixed cartographic geometry (ortho-images in UTM/WGS84 projection). It is a result from a digital elevation model to project the image in cartographic coordinates. This processing level using resampling a constant Ground Sampling Distance of 10, 20 and 60 m based on the native resolution of the different spectral bands. The product was compressed by JPEG200 algorithm and a GML geographic imagery encoded header (Sentinel 2 User Handbook, 2015). Similar to Sentinel 2, the Sentinel 1 includes two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar (SAR) imaging, and acquiring images regardless of weather. Level 1 – Ground Range Detected (GRD) was used in this research, data products contained single polarisation VH (vertical transmit and horizontal receive) and VV (horizontal transmit and vertical receive).

Two satellite images were downloaded at the close time; field values were recently collected. Images of the study area from Sentinel 1 and 2 satellites:

Table 1. Sentinel images for processing

No	Image codes	Date	Resolution
1	S2A_MSIL1C_20171217T032131_N0206_R118_T48QXH	17/12/2017	10m
2	S1A_IW_GRDH_1SDV_20171216T105736_20171216T105801_019727_02189C_78A3	16/12/2017	10m

Source: https://scihub.copernicus.eu/dhus/#/home.

RGB views of the study area from Sentinel 1 and 2 satellites:

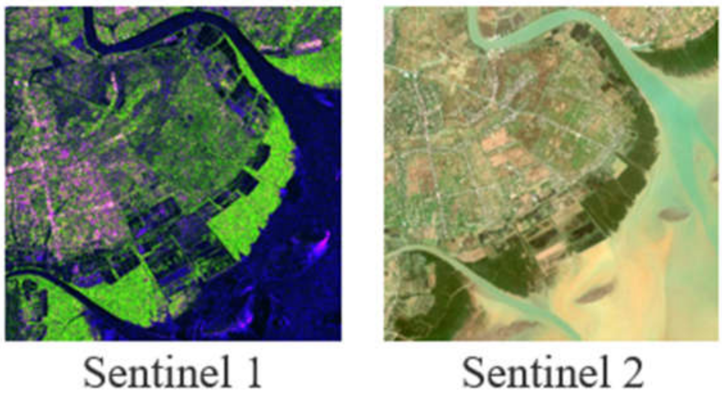

Figure 2. Sentinel 1, 2 at the study site

2.3. Methodology

2.3.1. Field data collecting

15 sample plots (10 m x 10 m) was implemented, 10 sample plots for making estimating model and 5 sample plots for evaluating. The diameter at breast height (DBH) and the height of the tree (H) were collected in the field.

2.3.2. Satellite images processing

Image classification: Sentinel 2 with different bands combination (10 m resolution) was used with Maximum likelihood classification in ArcGIS 10.5 software. The Kappa accuracy was used to evaluate the accuracy of classified map based on the real land-use type points collecting by GPS.

Vegetation indices: Sentinel 2 level 1C contains top of atmosphere reflectances. All the vegetation indices can be extracted in SNAP software automatically. The traditional vegetation indices for estimating biomass of mangroves in remote sensing are NDVI (normalized difference vegetation index), SAVI (soil-adjusted vegetation index), closely related to standing biomass (Kalaitzidis, Heinzel et al., 2010). Equations:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

$$SAVI = \frac{(NIR - RED)}{(NIR + RED + L)} \times (1 + L)$$

Where, L = 0.5 (canopy background adjustment factor to minimize soil brightness variations), RED: band red (04), NIR: near infrarred (08) of Sentinel 2.

SAR Sentinel 1: Preprocessing in SNAP desktop software: Subtract → Calibrate → Noise removal → Filter speckle → Terrain Correction → Extract backscatters (dB) (Veci, 2016).

According to previous researches, there is a strong positive relationship between biophysical parameters (height, DBH, canopy) and biomass with the exception of tree density (Pham, Yoshino et al., 2017). In addition, there are considered that primary scatters in radar applications in the forest, included biophysical parameters have backscatters produced and induce signal attenuation. The SAR data with VH, VV polarizations are well inputs to examine the relationship between biomass and backscatters. This study also tested the use of ratio VH/VV and VV/VH to discover their relations. Therefore, backscatters VH, VV, and VH/VV, VV/VH were used for regression modeling.

2.3.3. Estimating biomass and carbon stock for mangroves

Allometric equations:

$$AGB = 0.251 \times \rho \times DBH^{2.46}$$

$$BGB = 0.199 \times \rho^{0.899} \times DBH^{2.2}$$

Where, AGB: Aboud Ground Biomass (kg) and BGB: Below Ground Biomass (kg) (Komiyama, Ong et al., 2008). ρ is wood density (ρ = 0.340 applied for S. caseolaris, DBH is the diameter at breast height (cm).

Estimating from the relationship between allometric equation values and images indices: Using linear and curve regression to make the relationship between field values and image indices.

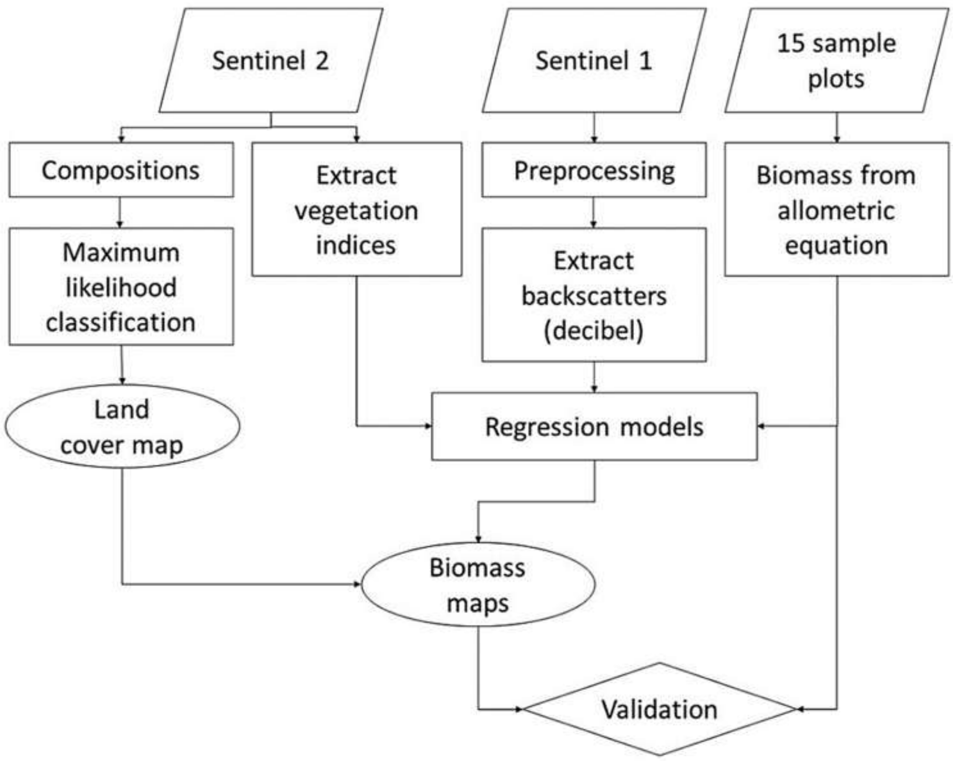

Figure 3. Workflow of research

3. RESULTS AND DISCUSSION

3.1. Field survey results

Based on the difficulty of collecting data such as labor cost, inundation time of the day, the study carried out 15 sample plots. 10 sample plots to build relationships, 5 remaining sample plots to evaluate the model. This is also the limitation of the study. There were 171 trees in 15 standard plots collected in the field, according to the results of the survey of local people, the mangroves here have been planted aged from 2 to about 50 years. The number of trees in a standard plot ranged from 4 to 22, with an average density of 11.4 trees per 100 m^2.

After field data collecting, above and below ground biomass were calculated by the allometric equation and these values were assumed as real values of biomass for each plot (100 m^2).

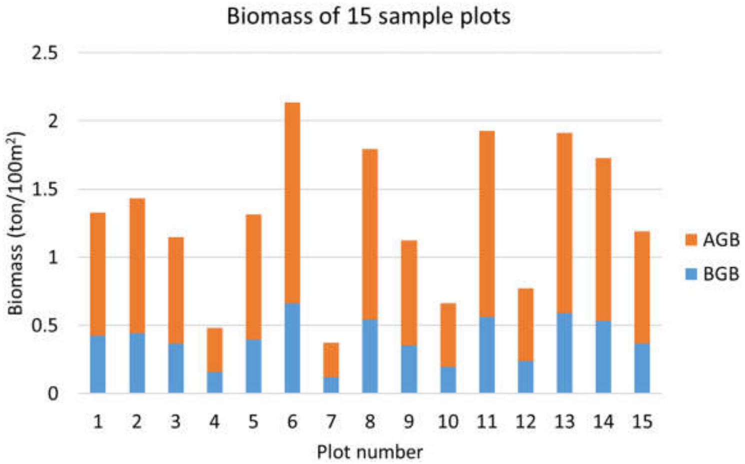

Figure 4. Above and belowground biomass of sample plots

In all sample plots, most below ground biomass equaled one third aboveground biomass. Depending on the location, a number of individual trees, heigh and diameter were much different. Maximum value: 2.13 ton/100m^2, minimum value: 0.37 ton/100m^2 and average value: 1.28 ton/100m^2.

3.2. Land cover map

The land cover map was created in ArcMap 10.5, using the Maximum likelihood classification method.

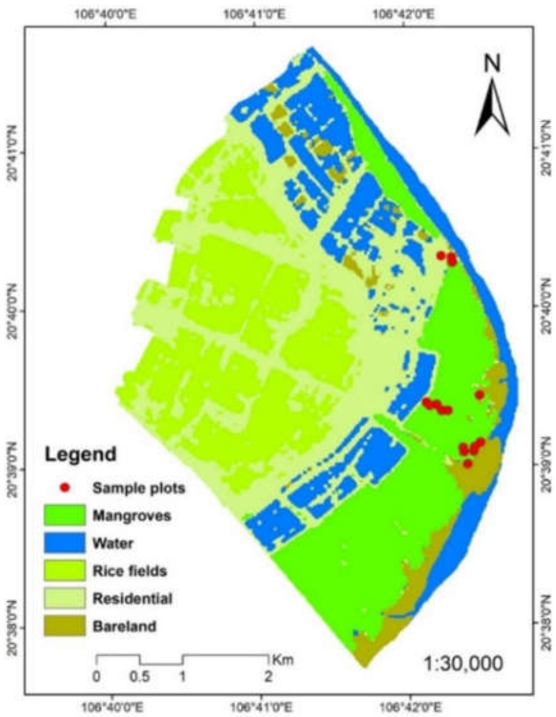

Figure 5. Land cover map

Mangroves area: 443.83 ha. Kappa accuracy assessment value for a classified map: 93.6% Kappa, based on 100 random real points. The mangroves area occupied 22% of Vinh Quang commune, equal a half of rice fields.

3.3. Estimated equation from field data and satellite image values

3.3.1. Vegetation indices and backscatters

The indices were calculated automatically based on built-in tools of desktop SNAP software. Looking at the NDVI and SAVI indices, the vegetation index was not high (compared to a maximum of 1), as NDVI and SAVI show green leaf color compared to the dark green color of *S. caseolaris's* leaves (Table 2). A number of standard plots indicated quite low values, corresponding to standard plots with low tree density. However, for VH and VV there was unevenness and little relevance. Summary of vegetation indices and backscatters in 15 sample plots from Sentinel 1 and 2 images.

Table 2. Summary of vegetation indices and backscatters

	NDVI	SAVI	VV	VH	VH/VV	VV/VH
Max	0.48809	0.27098	-4.10376	-9.17286	2.87726	0.77196
Min	0.10821	0.04988	-8.86718	-13.71280	1.29540	0.34755
Average	0.32577	0.16085	-6.98257	-11.61832	1.70919	0.60429

3.3.2. Biomass estimation

Through the various regression tests, the equations correlate with individual vegetation indices and backscatters as shown in the table 3:

Table 3. Estimated equations for biomass relating to images indices

Indices	Equations for Biomass (ton/ha)	R^2
NDVI	Biomass = $378.81 \times NDVI^{1.0191}$	0.719
SAVI	Biomass = $655.4 \times SAVI^{0.924}$	0.705
VV	Biomass = $141.52 \times e^{0.0437VV}$	0.010
VH	Biomass = $3.44 \times VH^2 + .01.11 \times VH + 824.31$	0.353
VH/VV	Biomass = $- 40.48 \times (VH/VV) + 187.33$	0.105
VV/VH	Biomass = $- 642.66 \times (VV/VH)^2 + 854.33 \times (VV/VH) - 155.97$	0.122

In the above equations, the vegetation indices are more closely correlated with the biomass, whereas the VH backscatter represents a very weak correlation (Figure 6). The remaining indicators did not show a correlation.

The NDVI and SAVI vegetation indices have relatively close correlations with mangrove biomass. The correlation between Sentinel 1 backscatters was quite weak and almost irrelevant. NDVI has the closest correlation with biomass. In that, scattering VV did not follow any rule, VH showed a very weak correlation. Multivariate regression has been tested, however, these models were not exist because of P value > 0.05.

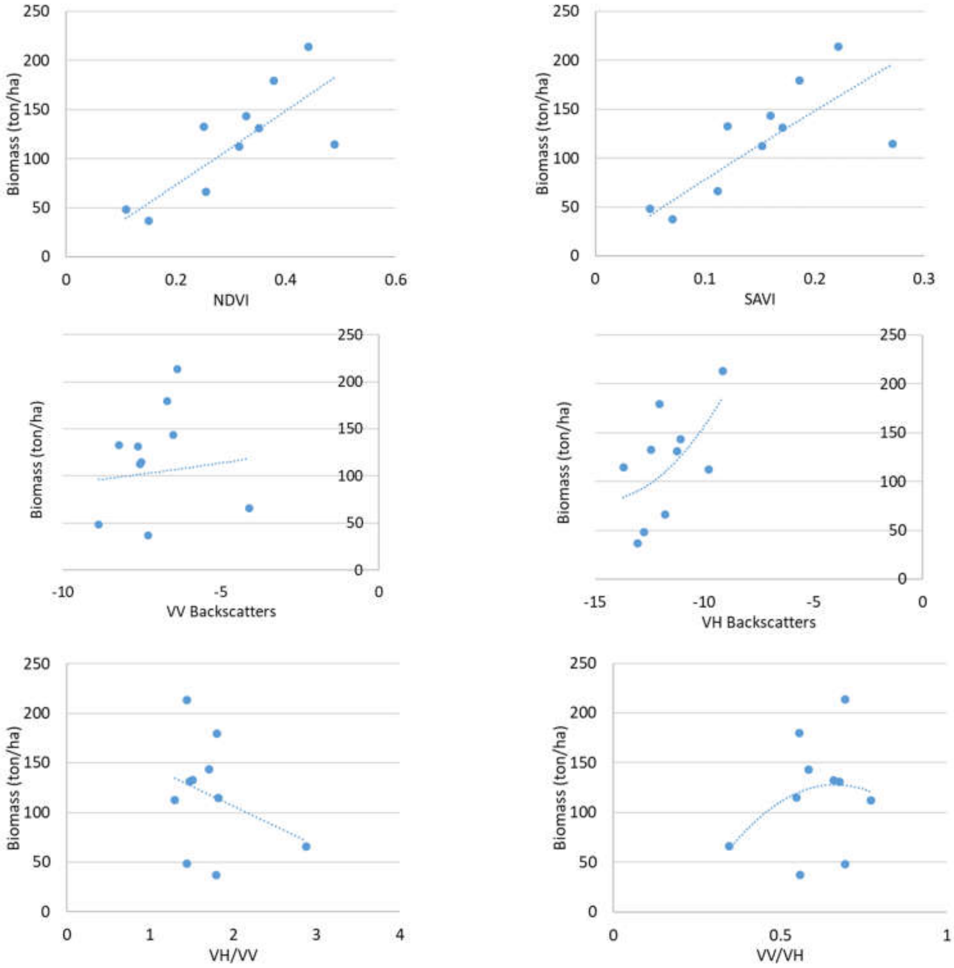

Figure 6. Relationship between vegetation indices, backscatters, and biomass

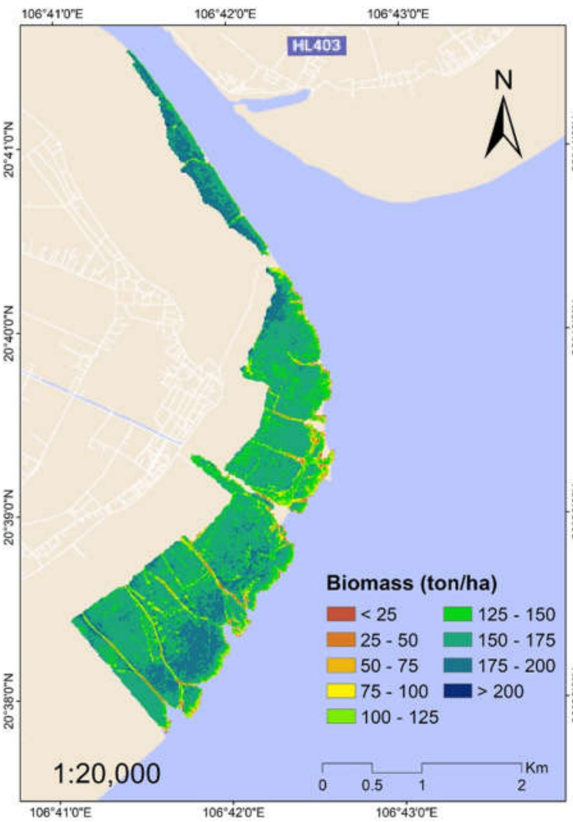

Figure 7. Biomass map of the Vinh Quang mangrove forest

3.4. Biomass maps

From the best correlation coefficient, NDVI, the author used ArcGIS 10.5 software to create biomass map combining with the classified area as mangroves for the study area (Figure 7).

Total biomass: 67,983.12 tons, average: 153.94 ± 27.01 ton/ha, maximum: 223.14 ton/ha. Most of the areas with low biomass were located and along the edges of the forest, ranging from 0 to 100 ton/ha. The major biomass value is from 125 to 175 ton/ha. Areas with high biomass value were long-standing forests, large canopy cover and tall trees that were concentrated to the north and near the south of the Vinh Quang commune.

3.5. Evaluating

The following results were based on the remaining 5 sample plots where the data were collected and calculated from the allometric equation.

Table 4. Evaluate the accuracy of biomass estimation by 5 sample plots

No	Allometric equation (ton/ha)	Estimated biomass from NDVI (ton/ha)	The difference (%)
1	1.928	1.638	15.1%
2	0.771	1.066	38.2%
3	1.912	1.335	30.2%
4	1.725	1.368	20.7%
5	1.190	1.365	14.7%
Ave.	**1.505**	**1.354**	**23.8%**

The difference between biomass from the allometric equation and estimated biomass from NDVI in the 5 sample plots ranged from 14.7% to 38%, with an average value of 23.8%, corresponding to 0.51 ton/ha. The accuracy of this method was relatively appropriate.

4. CONCLUSIONS

The land cover map was created efficiently in this study with high accuracy (93% Kappa accuracy assessment method). There were five land cover types: water body, bare land, rice crops, residential and mangroves. The classified map of mangrove was used for generating biomass maps from regression models.

The biomass was estimated by a combination of data from real field collection and image indices. Optical Sentinel 2 image indices have been more suitable for this estimation method in this case. NDVI and SAVI had better relationships with biomass and carbon stock (R Square around 0.7) compare to VH and VV backscatters, VH/VV and VV/VH having no relationship with mentioned tree indices. This regression approach is quite simple for making relations. Total biomass: 67,983.12 tons, average: 153.94 ± 27.01 ton/ha, maximum: 223.14 ton/ha.

The estimated results for biomass are appropriate with optical vegetation NDVI index. By evaluating value from the aromatic equation and estimated from regression model numbers, results were acceptable, 23.8% average for biomass. These results have been an evident that Sentinel 2 optical image provide better relationship than Sentinel 1 radar band C by 10 m pixel size resolution at commune scale with a simple regression model due to the short wavelength. With a higher number of plots, species and more completed estimation models, the results would be more applicable and can expand to a larger scale.

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ỨNG DỤNG TƯ LIỆU ẢNH SENTINEL TRONG ƯỚC LƯỢNG SINH KHỐI RỪNG NGẬP MẶN TẠI XÃ VINH QUANG, HUYỆN TIÊN LÃNG, TỈNH HẢI PHÒNG

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TÓM TẮT

Nghiên cứu này đã đánh giá việc sử dụng hệ thống thông tin địa lý cùng dữ liệu vệ tinh Sentinel 1 và Sentinel 2 để ước tính sinh khối rừng ngập mặn tại xã Vinh Quang, huyện Tiên Lãng, tỉnh Hải Phòng. 15 ô tiêu chuẩn (10 m × 10 m) được thiết lập để tính toán các mô hình ước lượng và đánh giá kết quả, ảnh vệ tinh được xử lý trong năm 2017 được cung cấp miễn phí bởi Tập đoàn ESA – cơ quan vũ trụ châu Âu. Nghiên cứu đã thành lập bản đồ phân loại sử dụng đất với chỉ số Kappa là 93%; bản đồ sinh khối từ các phương trình tương quan tương ứng. NDVI, SAVI là các chỉ số được trích xuất từ ảnh quang học Sentinel 2, tương tự tán xạ phân cực VV, VH, tỷ số VV/VH và VH/VV từ được trích xuất từ ảnh vệ tinh Sentinel 1A. Nghiên cứu chỉ ra rằng tán xạ từ ảnh vệ tinh Sentinel 1 không khả thi để xây dựng mô hình do chỉ số tương quan R^2 quá nhỏ. Đối với ảnh quang học, chỉ số NDVI thể hiện tương quan tốt nhất và được sử dụng để ước tính sinh khối, tổng sinh khối khoảng 67.983,12 tấn, giá trị trung bình: 153,94 ± 27,01 tấn/ha, tối đa: 223,14 tấn/ha. Bằng cách so sánh giá trị sinh khối từ mô hình sinh trắc và giá trị ước lượng, kết quả có thể chấp nhận được, sai số trung bình trong 5 ô tiêu chuẩn đánh giá là 23,8%. Nghiên cứu cho thấy ảnh quang học Sentinel 2 phù hợp hơn để ước lượng mô hình sinh khối rừng ngập mặn ở quy mô nhỏ, đặc biệt là ở cấp xã.

Từ khoá: Chỉ số thực vật, rừng ngập mặn, Sentinel 1, Sentinel 2, sinh khối.

Received	**: 27/7/2018**
Revised	**: 26/9/2018**
Accepted	**: 03/10/2018**